

Development of Glass Fibre Reinforced Gypsum (GFRG) Blocks Using Recycled and Waste Materials

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Abstract— This project investigates the development of Glass Fibre Reinforced Gypsum (GFRG) blocks using recycled gypsum (from waste gypsum boards), rice husk, chopped glass fibre strands, cement, and fly ash. Three mix designs were formulated with varying proportions of gypsum (40–50%), fly ash (20–25%), cement (15–20%), rice husk (10–15%), and 5% glass fibre. A total of 12 blocks (100 mm cube, 2.5 kg each) were cast and tested for compressive strength, water absorption, and density at 7 and 28 days. The expected results show that all GFRG blocks outperform traditional clay bricks, achieving 28-day compressive strengths of 4.0–4.5 N/mm² (vs. 3.5 N/mm² for clay bricks) and water absorption of 9–12% (vs. 18–25% for clay bricks). With recycled gypsum and rice husk obtained free from construction sites and local rice mills, the total material cost for 12 blocks is approximately ₹548 (₹45.67 per block). This project demonstrates that GFRG blocks manufactured from recycled and waste materials provide a technically superior, environmentally sustainable, and cost-effective solution for affordable housing construction.

Keywords— GFRG Blocks, Glass Fibre Reinforced Gypsum, Recycled Gypsum, Rice Husk, Chopped Glass Fibre, Fly Ash, Cement, Compressive Strength, Water Absorption, Density, Sustainable Construction, Affordable Housing, Waste Utilization, Eco-friendly Building Materials.

I. INTRODUCTION

The conventional construction industry is facing critical challenges due to environmental degradation, depletion of renewable resources like topsoil, and excessive energy consumption, creating an urgent need for eco-friendly and cost-effective alternatives. This project addresses these issues by utilizing waste materials such as gypsum (abundantly available from industrial byproducts), fly ash, and rice husk, reinforced with glass fibres to develop novel GFRG blocks.

Designed as a modular alternative to large panels for easier transport and handling, three mix proportions were evaluated with gypsum content ranging from 40–50%, fly ash 20–25%, cement 15–20%, rice husk 10–15%, and 5% glass fibres. This innovative walling unit offers significant advantages including a smooth surface finish that eliminates plastering, lightweight properties, excellent thermal insulation, and reduced environmental impact through minimized resource extraction.

The primary objectives are to:

- Create a sustainable substitute for conventional clay bricks
- Match or exceed traditional bricks in strength, water absorption, and durability
- Promote effective waste management and economic well-being
- Support India's need for mass-scale affordable housing

II. MATERIAL AND METHODS

2.1 Materials Used

2.1.1 Cement

Cement is the important binding material in construction. Ordinary Portland Cement was used in this research.



Figure 1: Cement

2.1.2 Fly Ash

Fly ash improves workability (due to round-shaped particles), reduces drying shrinkage and permeability, and increases ultimate strength and durability. It is a waste product from thermal power plants.



Figure 2: Fly Ash

2.1.3 Rice Husk

Rice husk comprises cellulose (50%), lignin (30%), silica (20%), and moisture (15%). It improves stability and workability, provides waterproofing and insulation properties, acts as a supplementary binder, and resists chloride, sulphate, and corrosion attack. It is an agricultural waste material.



Figure 3: Rice Husk

2.1.4 Gypsum

Gypsum acts as a long-term strength gainer, controls the rate of hardening, and is less soluble at high temperatures. It was collected from the fertilizer industry as a byproduct. The specific gravity of gypsum was found to be 2.4.

**Figure 4: Gypsum****2.1.5 Glass Fibre**

Glass fibres are common type of fibre-reinforced plastics arranged randomly, flattened into sheets, or woven into fabrics. They are cheaper, more flexible, and enable reduced block weight. Glass fibre is available in mesh or honeycomb form.

**Figure 5: Glass Fibre****2.2 Preliminary Tests for Materials****2.2.1 Gypsum Tests****Test 1: Determination of Standard Consistency (Vicat Apparatus)**

The standard consistency is defined as the water-to-gypsum ratio (%) that allows a 10mm diameter plunger to penetrate the paste to a point 5 ± 1 mm from the bottom of the Vicat mould.

Calculation: Standard Consistency (%) = (Weight of Water / Weight of Gypsum) \times 100

Test 2: Determination of Initial and Final Setting Time (Vicat Apparatus)

- **Initial Set:** Time elapsed when the needle fails to penetrate the paste 5 ± 1 mm from the bottom of the mould
- **Final Set:** Time elapsed when the circular attachment fails to leave an impression

**Figure 6: Vicat Apparatus****2.2.2 Cement Tests**

Test 1: Standard Consistency and Setting Time — Same procedure as gypsum using Vicat apparatus

Test 2: Fineness Test by Dry Sieving (IS Sieve 90 micron)

Calculation: Fineness (%) = $(W_2 / W_1) \times 100$ (Lower percentage indicates finer cement)

**Figure 7: Sieve Analysis****2.2.3 Fly Ash**

Fineness test using 45-micron IS sieve (instead of 90 micron for cement)

2.2.4 Rice Husk**Moisture Content Test:**

Calculation: Moisture Content (%) = $[(W_2 - W_3) / (W_2 - W_1)] \times 100$

2.2.5 Glass Fibre

Visual Inspection and Filament Count: Check for lumps, discoloration, or signs of moisture/damage

2.3 Methodology

Sr. No.	Step	Task for GFRG Blocks	Task for Clay Bricks	Importance
1	Get/Make	Blocks using specified mix proportions	Standard bricks	Fair comparison
2	Size and Weight	100 mm cube, 2.5 kg each	230×110×70 mm or 190×190×90 mm, 2.5–3 kg	Compare strength, etc.
3	Number of Samples	3 sets of 4 blocks each (Total 12)	3 sets of 4 bricks each (Total 12)	Evaluate at 7 and 28 days
4	Tests	Compressive strength, water absorption	Compressive strength, water absorption	Prove block superiority

2.4 Mix Design Proportions

TABLE 1
MIX DESIGN PER BLOCK (2.5 KG) – PERCENTAGE AND WEIGHT

Set	Recycled Gypsum (%)	Fly Ash (%)	Cement (%)	Rice Husk (%)	Glass Fibre (%)	Total (%)	Weight per Block (kg)
A	50	20	15	10	5	100	2.5
B	45	20	20	10	5	100	2.5
C	40	25	15	15	5	100	2.5

TABLE 2
MATERIAL QUANTITIES PER BLOCK (KG)

Set	Recycled Gypsum (kg)	Fly Ash (kg)	Cement (kg)	Rice Husk (kg)	Glass Fibre (kg)	Total (kg)
A	1.25	0.5	0.375	0.25	0.125	2.5
B	1.125	0.5	0.5	0.25	0.125	2.5
C	1	0.625	0.375	0.375	0.125	2.5

III. RESULTS AND DISCUSSION

3.1 Expected Results

Based on the material properties and mix designs, the following results are expected:

TABLE 3
EXPECTED COMPRESSIVE STRENGTH RESULTS

Set	7-Day Strength (N/mm ²)	28-Day Strength (N/mm ²)
A	2.8 – 3.2	4.0 – 4.3
B	3.0 – 3.4	4.2 – 4.5
C	2.6 – 3.0	3.8 – 4.1
Clay Brick (Control)	—	~3.5

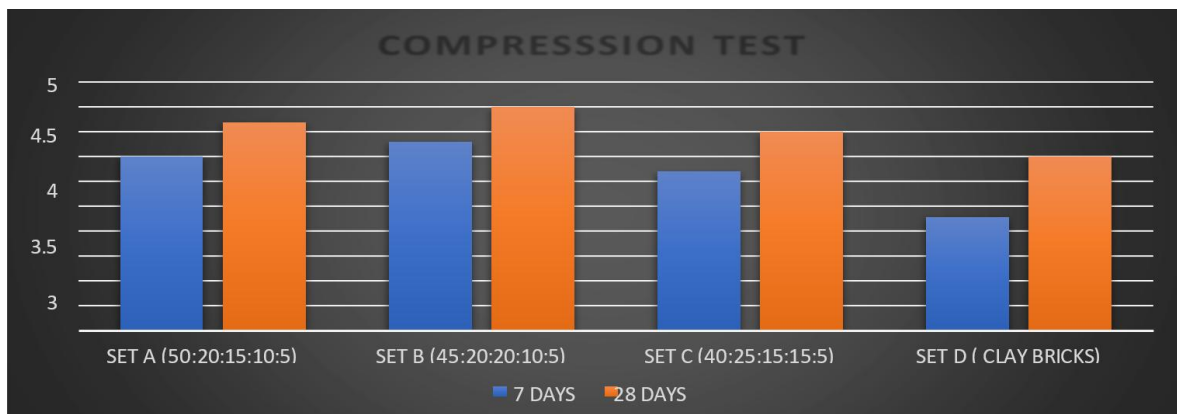


Figure 8: Compression Test

TABLE 4
EXPECTED WATER ABSORPTION RESULTS

Material	Water Absorption (%)
GFRG Blocks (Set A)	9–11%
GFRG Blocks (Set B)	10–12%
GFRG Blocks (Set C)	11–13%
Clay Brick (Control)	18–25%

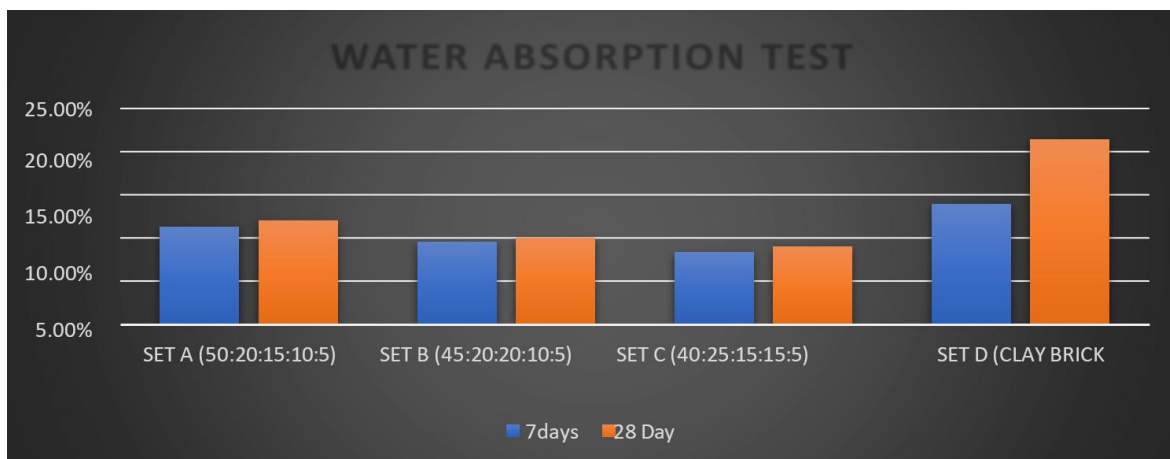


Figure 9: Water Absorption Test

3.2 Discussion

All GFRG block sets are expected to outperform traditional clay bricks in compressive strength, with Set B (45% gypsum, 20% cement) showing the highest expected strength of 4.2–4.5 N/mm² at 28 days. Water absorption for GFRG blocks is expected to be 9–13%, significantly lower than clay bricks (18–25%), indicating better durability and frost resistance.

The use of recycled gypsum and rice husk (obtained free of cost) makes the blocks highly cost-effective, with material cost approximately ₹45.67 per block.

IV. CONCLUSION

From this study, the following conclusions are drawn:

1. **Cost Effectiveness:** GFRG blocks are more economical compared to traditional clay bricks when recycled and waste materials are utilized.
2. **Awareness:** There is a need to create awareness about GFRG block technology among builders and homeowners.
3. **Sustainability:** GFRG blocks are eco-friendly, using industrial waste gypsum and minimizing cement, steel, sand, water, and labor input.
4. **Affordable Housing:** GFRG technology has the potential to meet the challenge of providing affordable mass housing in India.
5. **Material Cost:** Total material cost for 12 blocks is approximately ₹548 (₹45.67 per block) using freely available recycled gypsum and rice husk.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper. This research was conducted independently as part of an academic project without any financial or commercial relationships that could influence the results or interpretation of the findings.

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